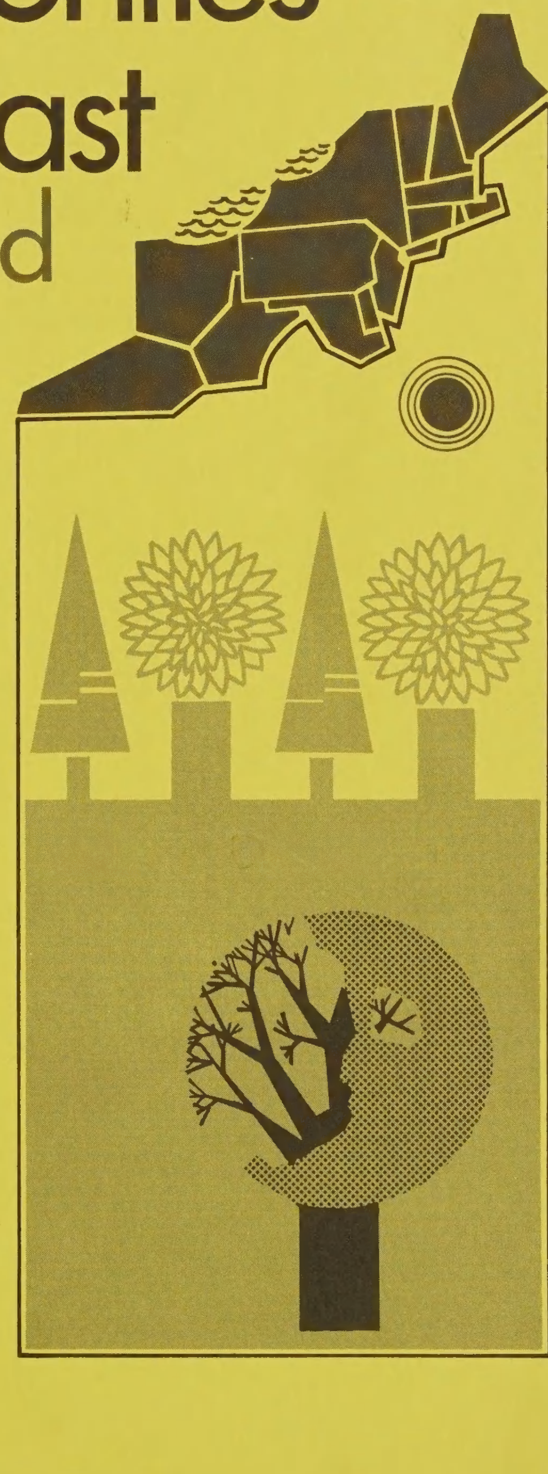
forest diseases research priorities in the northeast

a report prepared for the northeastern regional planning committee

northeastern forestry committee
forest diseases subcommittee
RP 2.03



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PREFACE

This research planning report was prepared as part of the Regional and National Agricultural and Forestry Research Planning System. The mission of this System is:

1. To further the research effectiveness of scientific talent and other research resources and,

2. To improve coordination between Federal, state, and private research organizations.

Research planning reports were prepared for fifteen forestry research subject areas. The reports will help accomplish the mission of the Planning System by helping:

1. to guide forestry research to the highest priority needs;

2. to avoid duplication of research efforts;

3. to coordinate research findings and to build on interim research results;

4. to assure recognition of emerging problems;

5. to provide advance information for adjusting research capability to research needs.

The subjects of the fifteen reports are:

2.01 Forest Inventory
2.02 Timber Management
2.03 Forest Insects
2.03 Forest Diseases
2.03 Forest Fire
2.04 Timber Harvesting
2.04 Forest Products Marketing
2.04 Forest Products Utilization
2.05 Forest Soils
2.05 Forest & Water Relationships
2.05 Forest & Air Relationships
2.06 Wildlife & Fisheries Habitat
2.07 Forest Recreation
2.08 Forest Land Use
2.09 Forest Economics, Policies, and Programs

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

I. LIST OF SUBCOMMITTEE MEMBERS

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II. SUMMARY TABLE OF PROPOSED RESEARCH

Title	Degree of Difficulty	Study Term	Information		Personnel Needs	Research Benefactor	Benefits		Risk		Priority
			Source	Adequacy			Direct	Indirect	Objectives	Use	
A. Wilt diseases	H	L	E,F,L	M	16	I,C,S	H	M	M	H	H
B. Diebacks and declines	H	L	E,F,L	L	16	I,C,S	M	H	M	H	H
C. Discoloration and decay in trunks of trees	H	L	E,F,L	M	15	I,C,S	H	H	H	H	H
D. Abiotic stress	H	L	E,F,L	L	12	I,C,S	H	H	M	H	H
E. Canker diseases	H	L	E,F,L	L	10	I,C,S	H	H	M	M	M
F. Root decays	H	L	E,F,L	M	10	I,C,S	H	H	M	M	M
G. Wood products decay	M	L	E,F,L	H	10	I,C,S	H	H	H	H	M
H. Nursery diseases	M	L	E,F,L	L	8	I,C,S	H	H	M	H	L
I. Foliage diseases	M	L	E,F,L	M	6	I,C,S	H	M	M	H	L
J. Rust diseases of trees	H	L	E,F,L	M	6	I,C,S	M	M	M	M	L

GUIDE TO SUMMARY TABLE OF PROPOSED RESEARCH

Title	Degree of Difficulty	Study Term	Information Source/Adequacy	Personnel Needs	Research Benefactor	Benefits Direct/Indirect	Risk Objectives/Use	Priority
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)

(a) Title of research need

(b) Degree of difficulty (an assessment by members of the research planning group) - designate High (H), Moderate (M), or Low (L).

High: complex, multi-objectives, multi-disciplinary requiring senior scientist direct, multi-person support and high operating budget.

Moderate: single objective, junior scientist supervision, moderate operating budget, one or two person support staff.

Low: single objective, junior scientist supervision, low operating budget.

(c) Study term: 5-year period or less is considered short term (s), anything greater is long term (L).

(d) Information needed: The research may be of the type which requires inventory and interpretation of existing data (E), field studies (F), laboratory studies (L), or any combination of these three. Use (O) for other if E, F, or L do not apply and explain (O) in a footnote. The adequacy of existing information can be shown as High (H), Medium (M), or Low(L).

(e) Personnel needs: Show number of Scientist Man Years. (SMY's) required for the research (SMY's are an indicator of both cost and time requirements).

(f) Research Benefactor: Show whether the major recipient and user of the research is: other Scientists (S), Federal Agencies (F), Other Public Agencies (P), Industry (I), the Public (C), or some other group (O).

(g) Benefits:

Direct benefits are -

High (H) where the results have immediate impact, are direct, and require little further work and synthesis. Medium (M) benefit is obtained from solutions to problems of lower priority, perhaps with an impact to small segments of the audience. Additional work is required to gain broader application. Low (L) benefit accrues to lower priority items or items which are very restricted in use, perhaps parochial. They may be one of a series of studies and require additional work or may be exploratory in nature.

Indirect benefits can also be shown as -

High (H), Medium (M), or Low (L). Strength of indirect benefits is indicated by such things as the potential use of this research to solve other problems, or use of the results as part of a broader, multi-resource type of problem.

(h) Likelihood of Success:

Both elements of this item can be classified as High (H), Medium (M), or Low (L). Objectives refers to the probability of reaching the objectives of the research. Use refers to the extent and likelihood that the research results will in fact be used.

(i) Priority: This is an overall research priority rating based on evaluation of all other elements in this table. Again, the priority should be shown as High (H), Medium (M), and Low (L).

III. INTRODUCTION

A. Background

The history of research in forest pathology in the Northeast is the story of reaction to crises. Goals and priorities have been a major ingredient sought but not achieved in forest disease research. Program priority, stability and depth have been constant victims of too many crises. First it was chestnut blight (circa 1905, the major impetus in getting tree disease research started). Next it was the white pine blister rust (circa 1910), then Dutch elm disease and beech-scale nectria (circa 1930). Then World War II with larch canker and birch dieback (1940-1950), then oak wilt, *Fomes annosus* root rot and maple decline (1950-1970). More lately, insect defoliation, salt damage, and air pollution. Now we are girding for urban stress on trees and acid rains. In a word, tree disease research programs, woefully understaffed, have responded to demands generated by crises with small attention to a long-range approach, and the record makes this apparent.

In spite of this, Marvin Fowler, former Chief of the Northeastern Forest Experiment Station's Division of Forest Disease Research, sensed a need for long-range planning, and prepared one of the first carefully documented plans for tree disease research in the Nation. 1/ This report, from which the present Task Force Subcommittee on tree disease research drew heavily, provided a valuable perspective and has served as a useful resource for this study.

One of the greatest deterrents to present and future productivity of forest land are the tree mortalities, growth reduction, and quality losses caused by diseases, fires, insects, animals and adverse weather. Of these, diseases present the greatest threat. In their loss impact, on forest productivity, diseases outrank by far the other destructive agents.

The numbers of perplexing and complex diseases that now threaten forests in the Northeast have created a great demand for research in forest pathology. Agencies that have a responsibility for protecting and managing our forests have a continuous need for up-to-date information about disease outbreaks and effective methods for controlling them. To fill this need is a major function of forest-disease research.

In the immediate future, forest-disease research should deal with those disease problems that concern all professionals engaged in multiple-use

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1/ Fowler, M.E. 1963. A guide to Forest Disease Research in the N.E., USDA, Forest Service, N.E. Forest Experiment Station, Upper Darby, Pa.

management of our forest lands. For example, though diseases of non-commercial trees and shrubs may be unimportant for timber production, they are often of great importance in recreation, watershed, wildlife management. Also forest disease research should deal with all tree disease problems including those of shade and ornamental trees in parks and residential areas.

The Northeast is unique in the United States as the single major region with representatives (including mistletoe infections) of every major tree disease type in the United States. It is also unique in being the earliest region struck and devastated successively by each of the three most important epidemic tree diseases in North America.

B. The basic research need.

While recognizing that primary considerations must be directed towards disease control, and thus towards applied research, it is essential to recognize the vital role that results from basic research contributions to achievement of satisfactory field control of tree diseases. In almost every case, basic research is essential to understanding the basic biological phenomena underlying the mechanism of pathogenesis. It is clear that we must understand these processes, so that we can apply meaningful control measures to achieve the best and most effective results in the applied research toward control. It is also clear that unexpected findings of basic importance often emerge from such research, and this knowledge often provides a new conceptual framework for applied effort toward control. In this sense, basic research efforts should be supported as parts of applied research projects where need arises naturally to understand basic underlying biological phenomena.

C. Interdisciplinary approaches to insect-disease related problems

In Northeastern United States some of the most damaging diseases are caused by insect-microorganism complexes: Dutch elm disease, Oak wilt, and Beech bark disease. Also there are many diseases that follow insect infestations; Spruce budworm and other defoliators. Fomes pini is known to invade leaders killed by the white pine weevil.

Entomologists and pathologists must work together on these problems. Emphasis in planning must be placed on defining the problem rather than on defining the specific portion of a problem that should be researched by an entomologist or by a pathologist. It will also be necessary for the scientists working on such problems to have a general understanding of the other's discipline.

D. Changing tree values.

The value of trees to be protected from disease will often determine how much control effort can be economically justified, and to some extent priorities in research. For example, a large oak in the forest may have a limited value of $50 for timber when it stands on undeveloped land; however, when the forest site with the same oak tree on it is converted to a country estate of high residential value, the oak may acquire within a year or two, a value exceeding $2,000, depending on size, form, beauty, location on the grounds, and health. Under forest conditions little disease control against oak wilt could be justified economically; however, as a landscape specimen tree of good health and beauty, such a tree could be injected with a systemic chemical for $50 to $100, because of its new value.

Over the Nation as the forests yield to residential or recreational development, literally millions of tree values are increased annually. This is a new aspect for justification of tree disease research that will continue to receive increased attention by the public and their representatives who make policy in the use of public funds. Such changing values merit serious attention for consideration of research priorities.

E. Operational procedure

The tree diseases in the Northeastern United States were grouped into 9 categories: Wilts, Diebacks and declines; Discolorations and decays; Root decays; Cankers; Rusts; Leaf diseases; Nursery diseases; and Abiotic stress. A tenth category was included for Wood Products decays. Ten specific categories were based also on causal agents or diseases per se: _Armillaria mellea_; _Fomes annosus_; Dutch elm disease; Oak Wilt; White pine blister rust; Oak decline; Maple decline; Pollution; Beech bark disease; and House rot. Pathologists in the Northeast rated the impact of the diseases as to hazards, aesthetics, recreation, economics, wildlife, water and air. The rating system gave 1 for low to 5 for high impact. The figures were then weighted as follows: hazard, 3; aesthetics, 2; recreation, 2; economics, 3; the others remained the same. The results were the following:

For the Disease categories --

High impact:

1. Diebacks and declines: 2. Wilts: 3. Decays: 4. Abiotic stress.

Moderate impact:

1. Root decay: 2. Wood products: 3. Cankers.

Low impact:

1. Leaf diseases: 2. Nursery diseases: 3. Rusts.

For the specific diseases within categories --

High impact:

1. Dutch elm diseases: 2. Maple decline: 3. _Armillaria mellea:_
4. Pollution: 5. Beech bark disease.

Moderate impact:

1. House rot: 2. _Fomes annosus:_ 3. Oak decline.

Low impact:

1. Oak wilt: 2. White pine blister rust.

Each major category with disease examples is reviewed in the following sections as to nature of its disease problems, the current status and loss potential, with broad research needs specified. Priority ratings and broad research needs are presented in Section II. - Summary Table of Proposed Research. A tabulation of the estimated disease

impact as judged by 12 Northeastern forest pathologists is provided (see Appendix).

Central points in the planning scope of this research review were:

(1) The unique characteristics of the region, including:
   (a) immense concentration of industry, population and wealth;
   (b) primary uses of the major land area for recreation, forest productivity and water resources;
   (c) and the longest and most intensive exposure of land (agriculture and forestry) in the United States to human impact,

(2) Needs of people in residence, including adequate open space, tree covered land and greenbelts for:
   (a) reserved recreational areas protected from erosion, pollution, and commercial exploitation; and
   (b) forest production to satisfy regional needs and industry;
   (c) forest and tree seedlings to increase environmental amenities.

(3) Contributions from the forest to include:
   (a) extensive and diverse recreational settings;
   (b) protection of soil from erosion and pollution;
   (c) products for local use and regional and national economic value; and
   (d) environmental modification of air and water to prevent or minimize pollution.

(4) Tree disease problems expected to be significant are those involving:
   (a) the economy with respect to forest productivity;
   (b) hazards that pose injury to humans or property;
   (c) aesthetics on recreational, urban and cultural sites; and
   (d) the environment, involving a multiplicity of stress factors.

F. General objectives.

These objectives underlie all of the general tree disease categories:

(1) To develop more effective methods to prevent disease loss;

(2) To increase growth and quality yields of major tree species affected;

(3) To enhance the quality of the tree-related environment; and

(4) To understand the basic biological processes of disease development.

IV. BROAD PROGRAM AREAS OF RESEARCH

A. Wilt diseases.

Nature of disease: Wilts of trees involve colonization of water conducting or food conducting tissues by microorganisms, leading to blockage of food and/or water movement, and to ultimate death.

Examples: Dutch elm disease; elm phloem necrosis; oak wilt; *Cephalosporium*; *Dothiorella*, *Fusarium*; and *Verticillium* wilts.

Current development and loss aspects: The wilt diseases generally, and Dutch elm disease in particular, are the most common and destructive diseases of woody plants in Eastern and Central North America. The American elm is the most susceptible of all elm species, not only to Dutch elm disease, but to elm phloem necrosis as well. Both elm diseases are lethal to most trees affected. The American elm is among the most populous hardwood species in almost all urban, suburban, and open country areas of the region. While several control methods are known to be at least partially effective in preventing new infections of Dutch elm disease, no method in itself can do more than reduce probability of infection for any individual tree, or enhance probability of recovery from an established infection. Dutch elm disease has been a growing epidemic in the Northeast for 40 years, has decimated thousands of urban and rural elm populations, and continues to spread and kill thousands of trees of all sizes annually. Oak wilt which reached epidemic levels up to 5 years ago, appears to have subsided.

Loss potential: Since spread of Dutch elm disease cannot be prevented on a massive basis, it can be expected to intensify and continue to reduce elm populations throughout the region.

Control status: In spite of the epidemiological nature of the disease, limited elm populations and single trees of high value can be protected from infection or induced to recover from early infections. While the established control methods of sanitation, spraying, and root severance are partially effective in preventing new infections, newer methods of pruning and chemical injection with systemic fungicides have great promise for enhanced recovery from established infections.

Research: Recent research has demonstrated the efficacy of new systemic chemicals and new delivery systems for increased distribution following stem or root injections, but these developments need much improvement and refinement. The variability of the pathogen must be determined to assess its pathogenicity in resistant elms. Because of increasing

evidence, the potential of developing tolerance to benomyl by C. ulmi, as has occurred with other plant pathogenic fungi, makes it essential to seek new systemic chemicals, as well as to develop a quick method to assay such tolerance. While selection and breeding of resistant elms continues to yield new species and varieties of much potential value, it is now apparent that insufficient attention has been given to variation in pathogenicity of the causal fungus which is now being explored in depth. Research on control of elm phloem necrosis by chemotherapy is being tested with mycoplasma-inhibiting antibiotics.

B. Diebacks and declines.

Nature of disease: Diebacks and declines are serious problems in the Northeast and nearly every major hardwood species has been affected somewhere within its range.

The onset of dieback and decline disease seems to be inseparably linked with environmental stress resulting from abiotic factors such as moisture or temperature extremes, chemicals, and air pollution or biotic factors such as severe defoliation by insects or fungi or attack by scale insects. These factors can result in changes in physiology, form, or structure of a tree that predispose it to attack by organisms that it resists normally.

Dieback/decline then refers to a progressive disease condition that begins when trees are altered by stress and continues as they become invaded by organisms of secondary action.

Research on dieback and decline diseases is often difficult because of the complex interaction of stress, host, and organisms. And studies should be initiated to include: effect of moisture extremes on roots; effect on roots of salt concentrations; relation of climatic changes to host susceptibility to disease; and the relationship between climate and hyperparasites. At least six diebacks-declines fall within the top four priority classes.

Disease examples: Maple decline, oak decline, ash dieback, and dieback and decline of many other species. Beech bark disease can also be classified as a decline.

Current development and loss aspects: Diebacks and declines of maples, oaks, and ash, have caused the most damage during the last decade. When trees in forested areas begin to dieback and decline, mortality can occur over very large areas. As some of these diseases develop in recreation areas the damage will increase greatly.

Loss potential: Diebacks and declines have the potential to kill large numbers of trees over large areas. It happened in the past when birch dieback resulted in massive mortality of birches in Northeastern United States and Canada. Oak decline has resulted in serious damage to oak forests in the northern and central range of the Appalachian Mountains. When these diseases occur they do so quickly over large areas.

Control status: Little can be done presently to control these diseases mainly because we do not have the means of controlling many of the environmental factors that initiate them. Salvage operations have been the only means of dealing with these problems. Where the initiating factor is defoliation, the insect population can be controlled.

Research: Research during the last few years has concentrated primarily on the effects of defoliation as the disease initiator and the defoliation-induced host changes that permit organism attack. This research has resulted in a model of the sequence of events and changes in the host that result in fatal attack by the root infecting fungus Armillaria mellea. This model should now be expanded to include other stress factors, hosts, and organisms such as the killing attack of beech by Nectria coccinea var. faginata following scale attack and twig fungi attack of ash in conjunction with drought.

A major research effort should concentrate on the identification of the resistant or tolerant trees and their mechanism(s) of resisting or tolerating stress and/or secondary organism attack i.e., drought cannot be controlled but we can select for trees that are drought resistant or disease resistant during drought conditions. New methods and criteria must be used to get the data. New electronic tools should be tested as indicators of vigor, stress or changes that are occurring in trees.

Special note: The Beech bark disease may be classified as a canker disease, an insect-fungus complex, or a decline. Because of this complexity some additional information on the disease is presented here. The Beech bark disease occurs when a bark-killing fungus, Nectria coccinea var. faginata, infects trees through minute wounds made by the feeding tubes of the beech scale, Cryptococcus fagi. The disease has decimated beech in many areas in forests of New England, and continues to move steadily in a south to southwestern direction. Although mortality usually results, many trees not girdled by the fungus are left with large necrotic areas on the trunks. Fungi that cause decays and discolorations invade the wood through these areas, and insects also attack the weakened trees. Little research has been done on the Beech bark disease since 1934. Some studies that need consideration are: selection of resistant trees; the relationship between the fungus and the scale insect; determination of the time from insect infestation to fungus infection; physiology of the fungus; the effects of environment on the insect and the fungus; biological control; long-range dissemination of the fungus; the roles of other fungi and insects in the disease; the succession of fungi infecting the cankers; and the effects of silvicultural measures on the spread of the disease. The close association of a major insect and a major fungus, and the confounding influences of other species of Nectria and scale insects such as Xylococculus betulae makes this disease truly complex (see Forest Insects Report 2.03 for related research needs).

C. Discoloration and decay in trunks of trees.

Nature of disease: Discolorations and decays are processes initiated by wounds. Small wounds may heal, larger ones rarely do. Wood discoloration is the result of early changes that involve chemical changes due to host response to wounding and later changes that involve interactions of pioneer microorganisms with the trees. Then cell contents are digested. Decay or disintegration of wood is the final stage of the process. Decay fungi digest the cell walls.

Examples: Discolorations and decays are associated with a wide variety of wounding agents: insects, animals, birds, fire, storms, and man and his activities. Wood discolorations range from black to all shades of colors - pink, red, blue, yellow, tan, etc. Decays are of two basic types: brownrots and whiterots.

Current development and loss aspect: Discolorations and decays are on the increase because of more frequent visits to the forest with larger mechanized equipment that results in not only more wounds, but more serious types of wounds. As demands increase for more high quality timber, the damage caused by discoloration and decay will increase. Shorter rotations may decrease the damage caused by some decays, but the damage caused by discoloration will become more important. Also, the increasing use of forests for recreational activities will increase the number of wounds, especially along campsites and roadsides. Here decays will not only cause the value of the tree to decrease, but the aesthetics and hazard potential will also be affected.

Loss potential: Decay is an essential natural process. We cannot stop it. The best we can do is to understand it so that more effective methods may be developed to regulate the process. In some cases we may want to speed up the process - slash removal, or for wildlife homes in trees - while in other cases we may want to stall the process. The potential for decay is not the primary question here, but the loss potential due to poor regulation will increase rapidly unless the decay process is clarified further. As with slash removal, or stand conditions that promote rapid decay of dead limbs, stalling decay can be just as damaging here as increasing its rate in tree stems.

Control status: Control of decay has always been thought to be an overwhelming situation. This has been primarily because the classical concept of decay was incomplete. Decay has become accepted as something that a person could do very little about,and efforts have gone to better ways of utilizing wood with various amounts of decay. Removal of obviously defective trees is the common method for control. But defects in trees that have few external indicators are the causes of considerable problems and of great economic losses. Effective control

methods are lacking because the nature of the decay process is not well understood by the managers.

Research: Current research on the decay process has centered about expanding the classical concept of decay. Concepts of successions of microorganisms and of compartmentalization of defects have been developed. The expanded concept of decay does give new hope for more effective control programs. But, before such programs can be started, more information must come from research on the mechanisms of the decay process. We need to know more about the tree defense systems, organisms successions in wounds and branch stubs, and how some microorganisms are able to surmount the chemical and anatomical barriers set up by the tree after wounding. We need to know the role of chemical toxicants in the delaying process and whether trees can be selected for such traits. We need to know more about the electrical dynamics in a living tree and the part it plays in regulating the defense systems or signalling decay development. Also, many new electrical tools are now becoming available, and must be used to help us understand the decay process and the normal and abnormal physiology of trees. A new age of tree science is upon us.

D. Abiotic stress.

Nature of disease: Trees affected by abiotic stress may be damaged by air, water, or soil, Such stress most often is caused from deficiency or excess of water and/or nutrient requirements, but may involve aerial or soil absorption of chemicals toxic to plant tissue.

Disease examples: water deficiency; iron deficiency; soil toxicity; and air pollution toxicity.

Current development and loss aspects: Damage to woody plants from abiotic stress is increasing annually, as the environment is being modified through economic development and technology. Not only is the soil in which woody plants grow being altered, but the air on which all non-aquatic life depends is filled with chemicals, toxic to plant growth. While it is not possible to assess accurately the economic losses, it is clear that certain crops can no longer be grown in urban areas of high air pollution, many plants will die, many will be reduced in yield, and the aesthetic value of others will decline.

Loss potential: The potential loss from abiotic disease can only be surmised, but it is now clear that whatever the cause, the photosynthetic mechanism of the plant will be impaired, and the net result can only be to jeopardize the future yield and survival of individual plants, plant populations, as well as survival of certain species of plants. What this could mean to trees per se can only be speculated, but it is clear that the future promises increased stress.

Control status: However difficult, the possibility of living with abiotic stress, since stress is likely to be increased rather than abated, measures are being sought to mitigate damaging effects. Studies are underway to identify plant toxins damaging to other plants, in screening plants for resistance to various air pollutants, in selecting for pollution resistance and with use of chemicals designed to minimize damage.

Research status: Work is in progress to evaluate the impact of specific air pollutants to trees under field and laboratory conditions; to seek resistant and susceptible varieties to certain air pollutants for monitoring studies; and to assess the impact of so-called acid rains on plants and soils. Much effort is being expanded on the mechanisms of pathogenicity to plant tissues by specific antibiotics. Chemicals to alleviate air pollution stress are being tested and used. In the area of allopathy, many new antibiotic compounds must be identified from plants that are toxic to the roots of other plants, and the nature of such toxicity must be explored (see Forest Air Relationship report 2.05 for related research needs).

E. Canker diseases.

Nature of diseases: A canker is a localized lesion or a dead spot on a tree. The dead area can assume various shapes, but when it circles the tree, it dies. Canker-causing microorganisms usually infect and invade broken branch stubs and other types of wounds. Cankers can cause damage to all species of trees of all ages. Remember - one of the most damaging and severe tree problems in the world was a canker disease - the chestnut blight.

Examples of diseases: Trees in Northeastern United States are infected by a wide variety of canker-causing microorganisms: (species in genera) Cytospora, Hypoxylon, Eutypella, Fusarium, Nectria, Strumella, Ceratocystis, Endothia, and many others too numerous to mention. Some cankers may also be caused by bacteria, especially on species of Populus. One of the most damaging diseases in the Northeastern United States is a canker disease - the beech bark disease. This disease is caused by species of Nectria (mostly N. coccinea var. faginata, and N. galligena), that infect wounds made by the beech scale, Cryptococcus fagi. A canker disease of aspen, Populus tremuloides, is a limiting factor in its economic values in the Northeast. The canker is caused by Hypoxylon mamatum. Some cankers are annual - such as those caused by Fusarium spp. on a variety of tree species - while others are perennial. Some Hymenomycetes cause perennial cankers. These cankers are termed canker rots. Some of the most damaging cankers are caused by canker rot fungi - Polyporus glomeratus, Poria obliqua, and Fomes pini.

Current development and loss aspects: The beech bark disease is moving westward and southward at a steady pace. It is moving into urban areas, parks, recreation areas, and beech forests. It is a major cause of damage. Little is being done to stop the disease. Little is being done to even understand the disease. The Hypoxylon canker on aspens continues to cause severe damage. The disease is a major factor in the profitable growth of aspen. Yet, we still do not know enough about the disease to develop effective control measures. Strumella cankers on young oaks cause defects and mortality at all ages. Here again we try to live with the problem. The list can go on and on.

Loss potential: The damage caused by canker diseases will continue to increase because no effective control measures are known. Cankers are also associated with trees under stress. So control here is linked to a better understanding of factors that initiate stress. In many areas only the high quality trees are cut and the defective cankered trees are left to regeneration - more canker susceptible trees.

Control status: Control centers about removal of obviously cankered trees. We have no good guidelines to do much more. We have also slowly accepted the fatality of the canker diseases and have done little to change the situation.

Research status: Most of the research on canker disease during the last decade has centered about *Hypoxylon* canker of aspens. Some other research has been on the annual canker of sugar maples - *Fusarium* spp. and a token amount on other cankers - basal canker of white pine, *Strumella*, *Eutypella*, etc. We need to know when, where, and how these canker microorganisms become established. We need to know the environmental conditions and the stand conditions that favor their establishment. We need to know whether the beech bark disease as it is known, is one disease or several diseases. We need to know the factors that affect the spread of the beech bark disease. Apparently there is a very delicate balance between the tree's defense system and the canker-causing microorganisms infection system. We need to know what we can do to give the tree the survival edge most of the time.

F. Root decays.

Nature of disease: Root decay fungi may attack all species of trees at all ages. Their destruction of anchorage and feeder roots are responsible for many windthrown trees and substantial reductions in tree growth rates. Some are associated with heartrot and other stem defect development in the lower tree bole. Root rots are particularly damaging in plantations and often cause mortality of younger trees. Some root decay fungi are virulent pathogens attacking healthy vigorously growing trees. In other cases environmental stresses due to drought, poor soils, air pollutants, and other factors appear to predispose some trees to infection by moderately parasitic soil-inhabiting fungi causing root death and decay, setting the stage for the development of decline and dieback diseases. Root decays are particularly insidious because their development and damages are often hidden from easy view. They are difficult to study because of the complex physical and biotic nature of soil systems and the relative inaccessibility of root systems.

Disease examples: Important examples of root decay fungi in Northeastern forests are Armillaria mellea, Fomes annosus, and Polyporus schweinitzii.

Current development and loss aspects: Armillaria mellea is a soil-inhabiting fungus attacking both agricultural and forest plants worldwide in distribution and a common saprobe in the forest often found decaying stumps and forest debris. It spreads through the soil by rhizomorphs which directly penetrates roots. It attacks trees which are stressed by drought, poor soils, or insect defoliation. This pathogen plays an important debilitating role in many decline and dieback diseases. It is responsible for tree mortality in many coniferous plantations. Its loss potential is judged to be important due to increased acreages of plantation grown trees and stressed trees in recreational and defoliated areas. Infection modes and development sequences, interactions with other soil organisms, and controls are not adequately known for A. mellea.

Fomes annosus causes a serious root rot primarily in pines. It causes substantial losses worldwide wherever pines are grown in plantations following thinning. It has developed into a major tree disease problem in southern forests and is intensifying in the Northeast. It is judged to be a serious future problem since so many plantations are at or reaching an age requiring thinning. This pathogen colonizes freshly exposed stumps, grows into the dying root system, and invades the adjacent roots of healthy trees. Extensive mortality and windthrow results in younger trees. Heartrot often develops in older trees, Extensive research has been conducted on this problem in Europe and the United States. In southern forests seasonal timing of thinnings during warm summer periods and stump treatments immediately after felling with

chemical or biological protectants are effective preventatives. In the Northeast, stump invasion may occur at any time during the growing season. The relative effectiveness of biologic and chemical treatments of stumps need refinement. Effective and economic ways to stop the spread of established infection centers need verification.

Polyporus schweinitzii is known to cause extensive heartrot in the valuable butt log of pines and other conifers, worldwide.

The heartrot is the brown cubical type associated with serious wood strength and pulping losses. Recent observations indicate this pathogen also may cause mortality, windthrow, and heartrot in young plantation grown conifers. Infection modes, developmental sequences, the effects of site factors, and controls are unknown.

Research objectives: (a) To determine the inoculum sources and timing; the dissemination modes, the infection courts; soil rhizosphere organism interactions; mycorrhizal associations; developmental sequences; soil-site relationships; and silvicultural, chemical, and biological preventions of the major root pathogens causing damage to Northeastern forests including A. mellea, F. annosus, and P. schweinitzii.

Evaluation and research approaches: Root decays are currently serious tree disease problems in the Northeastern region causing mortality, loss of growth, windthrow and basal log defects. Forest use and handling patterns suggest these problems will intensify in the future. Root decays are difficult to detect yet may involve windthrow hazards in areas of high recreational use (campgrounds, picnic areas, scenic vistas, etc.). Studies are needed to develop accurate ways to detect decay in anchorage roots and tree bases by external evidences (often subtle and fleeting) and physical measurements (electric, sonic, and X-ray) for critically located trees in recreational areas. Studies are needed to determine the effects of types and levels of root decay on the growth rates of high quality hardwoods and their predisposition to decline-type diseases (birch dieback, oak mortality, maple decline, ash dieback, etc.). Studies are needed to determine the major types of infection courts for the important root decays and how various modified forest operations (logging methods, cutting practices, etc.), silvicultural treatments, soil amendments, and site selections, may affect and minimize infection and development rates. For Armillaria mellea we need to know what biotic and physiological events occur in root systems permitting this general saprobe to become a serious pathogen under special ecologic circumstances. What are the resistance mechanisms permitting resistant trees to escape attack? What are the factors affecting rhizomorph development and pathogenicity? For Fomes annosus we need to determine the relative infection hazards throughout the region by major plantation sites, to develop reliable chemical and/or biologic stump

treatments, to develop effective ways to prevent pathogen spread from infection centers, and reliable ways to replant areas already invaded by the pathogen.

G. Wood products decay.

Nature of problem: Large volumes of wood are wasted each year from decay during roughwood storage and conversion when the wood is improperly handled or when wood is used in structures exposed to decay hazard conditions without effective preservative treatments or adequate designs to shed water and ventilate the unit. Some examples of these losses important in the Northeast are as follows: decays and discolorations which develop during the storage of high quality veneer or sawlogs; degrading discolorations of chemical (sti cker stain) or biotic (blue stains) origins which develop in lumber during air seasoning; discolorations and decays which develop in pulpwood chip storage piles; and the decays which develop in homes and other wood structural uses.

Examples: Such decay losses are estimated to approximate about 10 percent of the annual cut based on replacement uses alone. These losses are magnified by labor replacement and fabrication costs, hazards in use, and inconvenience. In large volume uses of wood involving standard sized items such as power poles, piling, or railroad ties, industry - aware of decay costs - uses effective decay control practices. A large scale business - the wood preservation industry - has developed to provide the wood preservatives, equipment, and techniques to provide the treated wood needed. Here future research progress in decay control lies primarily in increasing the effectiveness and uniformity of wood preservation treatments. This topic is the proper provenance of the RPA group dealing with wood utilization (see Forest Products Utilization report 2.04).

Current development and loss aspects: It is in the many general uses of wood under conditions conducive to decay, when wood must be cut and fashioned during assembly, and when both designers and users are uninformed about decay causes and controls that serious decay losses occur. This facet of wood protection has been a traditional concern and interest of forest pathologists, hence related research needs are presented in this section. Emphasis is placed on decay losses associated with homes and in various recreational uses of wood. It is judged that decay losses in these categories will increase as more wood is improperly used in various recreational units and by homeowners in "do-it-yourself" fabrication. For example, insulations improperly placed in homes to achieve energy savings may increase inner wall moisture condensation and set the stage for decay problems.

Control status: The control principles and general practices that will greatly reduce decays in any pattern of wood use are well known. National centers of excellence in the broad field of wood biodegradation and its control are operated by the U. S. Forest Service at the Forest

Products Laboratory at Madison, Wisconsin, and the Southern Forest Experiment Station at Gulfport, Mississippi. The staggering annual decay loss problem centers primarily around small wood processors, homeowners, and miscellaneous users of wood. A central need is to get the available information on decay prevention into the hands of architects and wood designers, homeowners, and the general public. This is a Public Service or Extension Project rather than a research need, but warrants special emphasis.

Specific regional needs exist for the development of reliable methods to detect decay in wood items in critical service installations, to minimize decay and discoloration development in pulpwood chip piles, to prevent sticker stains in high quality hardwoods, and to assemble key information on decay control in homes and devise effective ways to get it to designers, builders, homeowners, and other wood users.

Research objectives: (a) To develop methods to detect decay in early stages in critical structural uses by simple, effective, nondestructive means, (b) to develop a set of practices and procedures appropriate to the Northeastern region to minimize decay development in homes with emphasis on various uses of wood in recreational areas; and (c) to develop methods to minimize the development of discoloration and decays in pulpwood chip storage piles and to control sticker stain development during seasoning of high quality hardwoods.

Evaluation and research approaches: Early decay detection is important in critically placed trees potentially hazardous in high density use recreational areas and in other such structural uses of wood. Such monitoring techniques would permit maximum safe use and then removals or replacement when degree of hazard warranted. Electrical conductivity, sonic, and X-ray techniques have been used to detect early decay. The Northeastern Forest Experiment Station's leadership role in this area suggests that it might carry nationwide responsibility for this subject. There are indications that electrical conductivity tests detect early decay in a variety of wood uses. Conductivity data related to known amounts of decay by species collected for standing trees, bridge timbers, guard rails, poles, etc. would permit hazard monitoring programs in areas of potential user hazard and more effective use of wood.

While decay control practices in homes are well known there are indications that improper installations and uses of insulations may lead to extensive decay and paint peeling problems in homes. We propose an analysis of decay problems in homes and prevention procedures which would lead to a "Home Decay Prevention" bulletin placing emphasis on proper insulation uses and decay control in various recreational uses of wood such as cabins, docking, picnic tables, boardwalkways, etc.

Frequently during the air-seasoning of high quality hardwoods such as sugar maple, yellow birch, and cherry, grayish stains of chemical origin develop at the sticker crossing. The stains though of moderate intensity, are serious sources of degrade in hardwoods destined for natural finish furniture uses. There are indications that dipping the board in various anti-oxidants minimizes stain development. A study is needed to identify the chemical compounds in wood extractives serving as the chromogens and based on their structure to evaluate control chemicals, and develop effective preventative treatments.

Recently the chip storage of pulpwood has become popular increasingly. Advantages in addition to reduced decay and discoloration development are handling ease and small storage areas required. While effective handling procedures and chemical treatments are known for western and southern pulpwood species - effective controls for the Northeast need clarification due to the growing importance of hardwood pulping in the region. A study is needed to develop effective chemical treatments and handling procedures for the major Northeastern pulpwood species.

H. Nursery diseases.

Nature of disease: Nursery diseases involve a wide range of pathogens; the best known and the most studied are fungi of various pathogenic capacities from damping-off of seedlings to lethal stem cankers.

Disease examples: Nursery diseases caused by fungi include: damping-off by species of Pythium, Fusarium, and other genera; needle cast by species of Lophodermium and Rhabdocline; basal cankers through ant damage and canker fungi, such as Fusarium; needle rusts by species of Coleosporium; stem galls and cankers by rust fungi; and various root rots, such as those caused by Armillaria mellea. Crown gall of angiosperms is caused by a bacterium. Toxicity by one or more specific air pollutants represented newly described nursery disease problems.

Current development and loss aspects: Many diseases, relatively innocuous in native stands become more serious in the monoculture of nurseries and plantations. To the extent that such monocultures are increasing in number and acreage, infectious diseases of all types are expected to become more serious.

Loss Potential: Losses are expected to increase, especially with the introduction of new species into different ecotypes, such as Douglas fir in the Northeast, where needle cast diseases have been devastating. There are so many potentially damaging diseases in these monocultures that it is difficult to know how many and what pathogens are involved.

Control status: The control methods and procedures are as variable as the many different diseases, and vary in relative success or failure depending on the particular disease in question. Most controls are cultural or chemical. Certain diseases, such as needle casts, are extremely difficult to control for both ecological and economic reasons.

Research status: Most research involves biological studies of pathogens involved and exploration of chemical testing for disease control. There is a need for identifying the impact of suspected but unknown pathogens such as nematodes, mycoplasmas and viruses, assessing priorities for pathogens of greatest importance, developing resistant species, and for continuing the screening and exploration of new chemicals for control.

I. Foliage diseases.

Nature of disease: Most foliage diseases of trees evolve the colonization of leaf tissue by microbial pathogens such as fungi or bacteria, and result in relatively minor damage, unless large numbers of leaves are involved, extensive defoliation occurs or the pathogen infects contiguous woody stems.

Examples: Foliage diseases of conifers caused by fungi include: leaf-stem gall formations as in cedar - apple rust; needle rust, characterized by conspicuous blister-like fruiting bodies of the causal fungus; needle cast, characterized by extensive premature defoliation; and sooty mold, with surface tissues blackened by superficial fungus growth. Foliage diseases of angiosperms include: powdery mildews, featured by masses of superficial hyphae and spores; numerous leaf spots with circular delimited necrotic areas; anthracnoses, characterized by circumveinal necrosis, premature defoliation and twig cankers; leaf blisters, characterized by a deformity of leaf tissues; and sooty mold as on conifers.

Current development and loss aspects: The most serious of foliage diseases are the needle casts of conifers whose range have been extended beyond native habitats. Successive years of defoliation reduces yield and may kill or predispose trees to secondary parasites or predators. Even a single year of severe defoliation may result in serious economic loss from reduced aesthetic value (Christmas trees). Among deciduous trees, leaf anthracnoses are most destructive to certain species, such as sycamore, where the pathogen causes cankers and girdles stems. Both needle casts and anthracnoses are enhanced by the type of wet climatic conditions that prevail in the Northeast.

Loss potential: Needle cast poses a continual threat to conifers raised in monoculture as in Christmas tree plantations, and can be expected to result in increased economic damage as such plantations are increased in size and number. The anthracnose disease poses little direct economic loss for native trees on forest sites, but will continue to reduce aesthetic values in landscaped or street plantings.

Control status: At present there is no satisfactory control for leaf or needle diseases. Many chemical treatments and schedules have been tried but to date, none is considered satisfactory.

Research status: New efforts must be expended to determine the biology of the causal fungi of needle cast diseases. New systemic chemicals must be explored, new cultural features such as spacing must be studied and varietal resistance sought through selection and/or breeding programs.

J. Rust diseases of trees.

Nature of disease: All of the rust diseases involve primary invasion, parasitism and necrosis of host tissues, ranging from innocuous leaf spots to the girdling of large stems.

Disease examples: Rust diseases of trees include: a wide variety of conifer-angiosperm rusts, such as cedar-apple rust, characterized by malformations of the coniferous hosts; needle rusts described also as foliage diseases; stem gall rusts, characterized by tumor-like galls; and stem-canker rusts, such as white pine blister rust, characterized by canker-like swellings that destroy stems affected.

Current development and loss aspects: Except for stem rusts, most rust diseases are considered relatively innocuous;while the stem gall diseases continue to damage hard pine plantations, their economic impact is not substantial. However, white pine blister rust (a stem canker disease) continues to destroy, or disfigure trees of all ages in native stands, in plantations, and increasingly on park, landscape and residential sites.

Loss potential: Damage and losses from white pine blister rust are expected to increase as inoculum increases on alternate hosts, where eradication has been abandoned, and is expected to become more visible to the public as aesthetic and recreational values are affected, and more hazards occur in residential areas. Loss potential from the repeating rust caused by Cronartium harknessii on hard pines should be considered serious, until and unless relative susceptibility of southern pine species is shown to be significantly low.

Control status: Relatively little is being done toward control of either of the two primary rust diseases of greatest potential damage. There never has been a control program for the repeating gall rust, because its potential threat has not materialized while not being discounted. Large-scale control of white pine blister rust by eradication of alternate host plants is now largely abandoned as economically prohibitive. Local control on residential sites is practiced by excision of infections on individual trees.

Research status: Most research on blister rust is now directed toward host-parasite relationships in an effort to understand mechanisms of pathogenicity. Extensive research efforts toward seeking disease resistance are no longer in force. Most research is needed on direct chemical control in individual trees, specially where used in combination with pruning and wounding. Research on the repeating rust on hard pines is needed to explore the epidemiology to ascertain its potential for spreading into hard pine stands including southern pine species.

V. RELATED RESEARCH NEEDS

A. Disease impact analyses.

To establish priorities for tree disease research, for funding, for planning and control, attention must be directed towards developing disease impact analyses procedures to determine losses, including economic and aesthetic values and developmental trends. There is a definite need for information concerning the relative importance of each serious disease problem. And such information is lacking at present. It is also important for long-term research considerations that research investigators initiate ideas, call attention to significant aspects of disease loss and cooperate at all times with projects designed to make impact evaluations. While the collection of this information should not be a primary responsibility of the tree disease research investigator, he should play a role in the design of such systems for detecting, monitoring, and evaluating total disease impact.

B. Biological control.

Another area of research requiring attention over a long period is development of biological controls. In most cases such controls will require detailed studies of the biologies of hosts, causal agents, and biotic agents and/or their products and should be considered for exploration only over a long period. To some extent, already existing cultural controls may be most effective through their influence on the complex biology of interaction assumed to be a constant factor in soils. Silvicultural controls probably represent special kinds of biological control, but we have only a vague concept of the mechanisms through which such controls appear to be effective. Too many generalizations assumed to be sound are based on assumptions for which there is little sound evidence. Thus, to the extent that foresters depend on silvicultural methods for disease control, it is essential for forest pathologists to provide a sound biological basis for justifying such controls.

The concept of biological control involves the use of ready-made biological mechanisms that operate naturally to the benefit of man, just as disease incidence from infection is a ready-made mechanism operating in the opposite direction. Thus, the key to understanding and using biological controls against causal agents of tree disease, is first to discover the defense mechanisms, and then to learn how they operate so that we may provide the environmental conditions under which they may be reinforced. For example, new information on presence of viruses in fungi offers many new potentially effective ways to disease control.

In this light we must also begin to learn what nature already has going for us, and how much if at all, it pays to push biological mechanisms already operating to our manifest advantage. For example, if natural biological control is already providing about 60 percent limitation of disease spread or development, and with chemicals we can obtain no more than 70 percent, it is essential to question on a cost-price basis, the value realized in the additional 10 percent, it may be more advantageous biologically as well as economically, to leave nature alone. But if this 10 percent is of vital importance, it is imperative to know more of the biological mechanisms involved to see how such a margin may be increased. The key to use of biological control is in UNDERSTANDING the biological interactions involved.

C. Mycorrhizal research.

Mycorrhizal research though not a specific portion of forest pathology *per se*, nonetheless is judged to be important and closely related to both basic and applied studies of tree disease. Mycorrhizae are symbiotic associations of the short roots of trees and fungi. Many species of fungi are known to be involved in these complex root associations. Mycorrhizae are now known to be present in essentially all forest trees and most agricultural plants. Mycorrhizal benefits to the tree are many including increased soil, water and nutrient absorption and the protection of many feeding roots from various pathogens. In some major reforestation attempts, mycorrhizal presence on the tree root system is known to be necessary for tree survival and growth.

Mycorrhizal research has expanded greatly in the past decade both on a national and a worldwide scale. Emphasis has been on identifying the fungal symbiont, studying the factors affecting their development, unequivocally establishing their beneficial role in tree nutrition, and elucidating the various complex physiologic interactions and developmental sequences occurring between the two symbionts. Recent research has established also the important protective role of mycorrhizae to tree feeding roots against pathogens and sought mycorrhizae which would enhance tree survival on dry sites and poor soils. In the United States, mycorrhizal research attention to date has been focused largely on Western and Southern timber species, and neglected in the Northeast.

Mycorrhizal research is believed to have great potential importance in the Northeast. A major need exists to first identify those fungal symbionts which impart special advantages to the tree such as planting survival, growth on poor sites, enhanced vigor, and growth and resistance to root diseases. A related need to develop practical techniques so that the beneficial mycorrhizal fungi can be introduced to seedlings and trees in nurseries, plantations or forests, and maintained during the major growth periods of the tree. More specific topics of potential promise in mycorrhizal research in the Northeast are as follows: to determine the identities and role of mycorrhizae in the growth and health of urban shade trees; to determine those mycorrhizae which might play a beneficial role in the reforestation of strip mine areas; to determine those mycorrhizae which might play significant protective roles against root rot and feeding root pathogens; and to determine the role of mycorrhizae in minimizing tree stress in the development of various decline and dieback diseases.

Additional mycorrhizal research needs of a basic research need and related to tree physiology and nutrition are more appropriately covered in other RPA projects dealing with tree growth and forest productivity (see Forest Soils 2.05 and Timber Management 2.02 reports).

D. Bioelectronics.

A new age of forestry is emerging. New electrical tools and new methods involving electrical devices will give us new opportunities to understand natural processes and to make more effective decisions of benefit to man.

Results of recent research using some new electrical devices show that dying, dead and decaying tissues can be detected in living trees. And active decay can be detected in some wood products. Also, research results suggest that the vigor of the tree may be detected by its electrical responses.

In the future, single trees or representative trees in an entire forest may be in touch with a computor by way of telemetry. The small sending devices in and on the trees will forecast all types of troubles. Certain trees may be sensitive detectors of developing air pollutant levels. The day may come when these methods will tell us which trees should be cut, which needs a fertilizer, which need certain treatments, and which are beginning to become a hazard. This new age is coming rapidly, and we must plan for it.

We need researchers who have training in bioelectronics. We must cooperate with electrical engineers now. If we do not include the use of electrical tools in our research plans now, we will be missing a golden opportunity!

E. Additional research needs.

Because we have used ten established tree disease categories as the basis for our review of proposed research, we have not given major consideration to certain other areas of research needs that merit attention. For the most part, these areas represent substantial gaps in our knowledge of tree diseases, and reflect to a degree the neglect of systematic planning, stemming from a crisis approach to research. Most of these areas have had such little attention because they represent no clearly-defined problem of pressing economic importance. But this may be an illusion based on ignorance. There are at least four major areas of research endeavor based on causal agents involved, where ignorance of real or potential forest disease problems, is a serious handicap to a realistic view of the challenges that may face forest pathology in coming decades.

Latent bombshell pathogens are those diseases of woody plants known or suspected to be caused by nematodes, bacteria, mycoplasmas, and viruses (and possibly viroids). There are vivid signposts that one or more of these may be a latent bombshell. At the very least, it is clear that their potential significance and impact have not yet been evaluated. It is also clear that any long-range program would be remiss to ignore the study of these pathogens with the evidence at hand. As examples, the vital role of bacteria in the decay process, could and should have been elucidated at least two or three decades ago; and the reality of the mycoplasma as a causal agent of elm phloem necrosis should have been examined at least 10 years ago.

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VII. APPENDIX

<u>A Tabulation of Disease Impact Estimates</u> -- Based on individual statements of committee members or contributors, perspectives drawn from background personal assessments of each disease category, a summary table of estimated disease impacts is presented here. These evaluations as presented here should represent a broad concensus by all of those who contributed. As indicated in the table, they reflect three orders of priority (H, M, L): and each disease in these categories is also arranged in order of descending priority.

Appendix Table -- Estimated impact and priority rating of tree diseases in Northeastern United States 1/

General Diseases	Weighted Totals												Total	Average	Priority Rating
	1	2	3	4	5	6	7	8	9	10	11	12			
Dieback & declines	58	43	13	47	39	44	51	54	53	49	51	48	550	45.8	H
Wilts	44	39	36	43	39	33	54	55	38	46	28	48	503	41.9	H
Stem Decay	33	38	31	36	58	47	36	35	34	45	47	33	453	37.8	H
Abiotic Stress	41	44	19	40	24	30	39	59	25	41	49	33	444	37.0	H
Root Decay	37	45	25	28	33	37	30	46	34	29	26	35	404	33.7	M
Wood Products	15	35	22	34	31	44	25	56	13	45	25	21	366	30.5	M
Cankers	34	49	13	19	25	31	29	29	41	23	19	26	358	28.2	M
Leaf Diseases	40	23	35	23	26	21	28	21	36	27	27	15	322	26.8	L
Nursery Diseases	36	27	35	19	24	22	28	29	26	19	19	16	300	25.0	L
Rusts	32	26	32	16	25	25	21	29	27	13	19	33	298	24.8	L
Specific Diseases															
Dutch Elm Disease	52	39	28	42	37	40	55	55	45	46	30	41	510	42.5	H
Maple Decline	43	42	13	45	37	29	51	53	45	43	30	31	462	38.5	H
Pollution	59	18	19	33	31	28	21	59	39	28	19	35	389	32.4	H
A. mellea	32	45	22	40	27	33	27	46	25	47	18	26	388	32.3	H
Beech Bark Disease	51	13	20	43	33	39	28	30	16	42	32	30	377	31.4	H
House Rot	45	13	19	29	23	42	26	38	-	45	25	31	336	30.5	M
F. annosus	34	43	13	26	27	31	32	36	25	26	13	23	334	27.8	M
Oak Decline	32	32	13	45	21	33	23	-	18	46	16	26	305	27.7	M
White Pine Blister Rust	32	13	13	18	25	26	28	17	39	13	20	26	270	22.5	L
Oak Wilt	36	20	13	22	21	28	31	-	13	20	17	26	247	22.4	L

1/ As judged by 12 Forest Pathologists working in the Region.